



# AL HAJAR

Geological Society of Oman  
Quarterly Newsletter



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## President's message

Dear GSO Members,

The society, now ten years old, continues to make excellent progress and this was celebrated in the Annual General Meeting held in the Crowne Plaza Hotel on the evening of Saturday 26th February 2011.

The lively team of young geologists from SQU who had produced the new "Geo-Tourism" booklet was celebrated, as were the many geologists who had contributed talks and field excursions over the year.

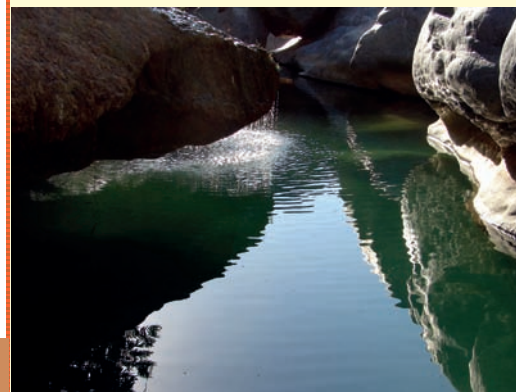
2010 was a record year for membership growth, with 99 new joiners, which is very encouraging. It was also a pleasure to introduce the new GSO executive committee for the 2011-2013 term. Progress in several of the society's projects was reported.

As always let me thank the members of the society for their commitment and contributions and encourage members to forward views and suggestions to any of the members of the executive committee.

Regards,

**Dr. Mahmood Saif Al Mahrooqi**

President GSO



## Note from the Editor

Greetings all,

Welcome to this, the 18th edition of Al Hajar.

Congratulations to all involved in a fine AGM last month! It was good to see such a full room and everybody enjoyed Ali Al Lazki's geological and geophysical tour of the Arabian Plate. Please visit the report online at [http://www.gso.org.om/Annual-Report/Annual\(2010\).pdf](http://www.gso.org.om/Annual-Report/Annual(2010).pdf) to read about progress with the society's various projects and to see the GSO executive committee for 2011-2013.

What do we have for you in this edition of Al Hajar? In addition to the regular sections on fieldtrip reports and exploration news in the region we have a fascinating article on the young geological record of the Omani coast and another providing new insights into the geology of Dhofar. As always we are delighted to read your feedback on the articles published in Al Hajar.

Enjoy!

Ru Smith

GSO Editor

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For Internal Circulation Only

## Field trip report

### WADI MISTAL FIELD TRIP: Geological archives recording frequency and intensity of (Late) Quaternary precipitation events

By Fernando Teixeira da Silva, PDO

This field trip to the terrestrial deposits exposed in Wadi Mistal, currently under study by Dr. G. Hoffman (GUTech) and M. Rahn (RWTH Aachen University), took place under cloudy skies and with some rain, very much in line with the subject of their ongoing work. The current

research project aims to improve our understanding of the frequency and intensity of precipitation during the wetter periods of the Late Quaternary in Oman, with an emphasis on the Al Batinah coastal areas.

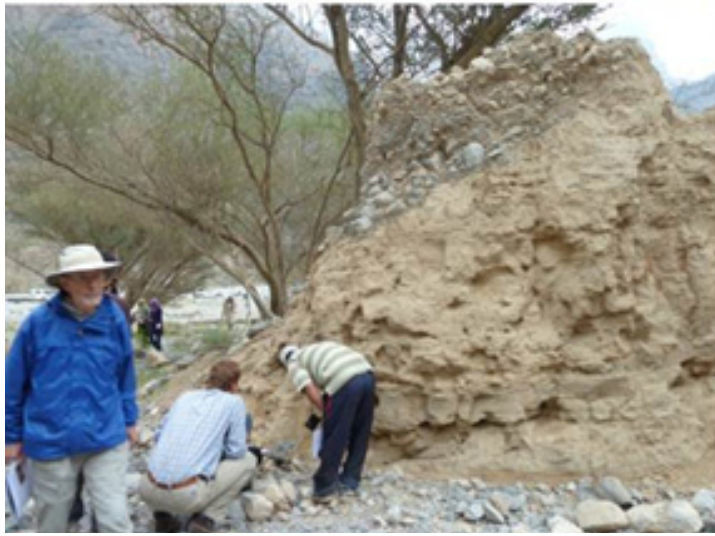


Fig. 1 - Dark Skies and cloudy peaks could be seen from the main road leading into the wadi

The most relevant outcrops visited are of buff to yellowish color fine-grained sands and silts with high clay content, locally showing a lateral facies shift to coarser (sand to gravel) deposits. Different sedimentary structures can be observed such as horizontal and wavy

lamination, cross-bedding as well as desiccation cracks. Some in-situ plant remains (roots) are also identifiable along palaeo-surfaces, these being indicative of sub-aerial exposure during long dry periods.





**Fig. 2 – Two of the visited outcrops showing the rather homogeneous aspect of the fine-grained sands and silts with high clay content.**

Up to 130 fining-upward cycles showing a clear transition from silt at the base to clay at the top were identified and are considered to be geological evidence of intense precipitation events which affected the re-

gion during Late Pleistocene-Quaternary time (Bray, H.E. & Stokes, S. – Temporal patterns of arid-humid transitions in the South-Eastern Arabian Peninsula based on optical dating; *Geomorph.* 59; 2004).



**Fig. 3 – Some examples of the fining-upwards cycles observed on the rocks at the outcrops. Each sequence is interpreted as evidence of a high precipitation episode affecting the area.**

The outcrops represent the erosional remnants of a more widespread deposit, which probably covered the entire wadi. The fine grained sands and silts are interpreted as limnic sediments accumulated in a perennial lake and associated with very high precipitation episodes similar to present day tropical storms and cyclones. The lake probably resulted from the closure of the wadi by massive

landslides which obstructed the narrow gorge. (Rhahn, M. (in prep.) – Sedimentary evidence for landslide damming in Wadi Mistal, Sultanate of Oman – Fakultät fuer Georessourcen und Materialtechnik, Lehr- und Forschungsgebiet Neotectonic und Georisiken, Rheinisch-Westfälische Technische Hochschule Aachen, BSc. Arbeit).



Fig. 4 – A modern depositional analogue for the rocks observed in the field. Light coloured deposits at the base of a modern water retention dam constructed not far from the outcrops.

The final results from the ongoing work are to be integrated with available instrumental and historical data to estimate the vul-

nerability of the coastal areas along the Al Batinah region to catastrophic events like hurricanes, flash floods and tsunamis.



Fig. 5 – Group photo of field trip participants and a colorful example of the local fauna.



# Short- and Long-term Environmental Changes along the Coastline of Oman

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## 1 Introduction and aims

### 1.1 Aims

The German University of Technology in Oman (GUtech), Department of Applied Geosciences is conducting joint research projects with RWTH Aachen University, Department of Neotectonics and Natural Hazards. The project titled “Coastal evolution of the Sultanate Oman (Arabian Peninsula) - tectonic versus sea-level forcing” received funding from the German Science Foundation (DFG) in 2010. A corresponding project, titled “Short- and long-term environmental changes along the coastline of Oman (Arabian Peninsula)”, was recently accepted by the Omani Research Foundation (TRC). The two projects are complementary to each other and allow a holistic and interdisciplinary approach on coastal changes.

The overall aims of the projects are: a) revealing the site-specific factors influencing coastal

evolution along the coastline of the Sultanate of Oman; b) reconstruction of the relative sea-level development during the Quaternary; and c) quantification of uplift and subsidence rates of the coastlines during the Quaternary. Tectonic implications can be derived once the spatial relationship of the different forcing factors is known. Furthermore, the nature and recurrence intervals of natural hazards that are threatening the coasts will be analysed. This will help to mitigate damages. Finally, strategies will be outlined to secure a sustainable development for the Omani society. Final results are expected in 2014. The aims of this article are to give an overview of the projects and to present preliminary results of reconnaissance surveys along Oman’s coastline (see figure 1).

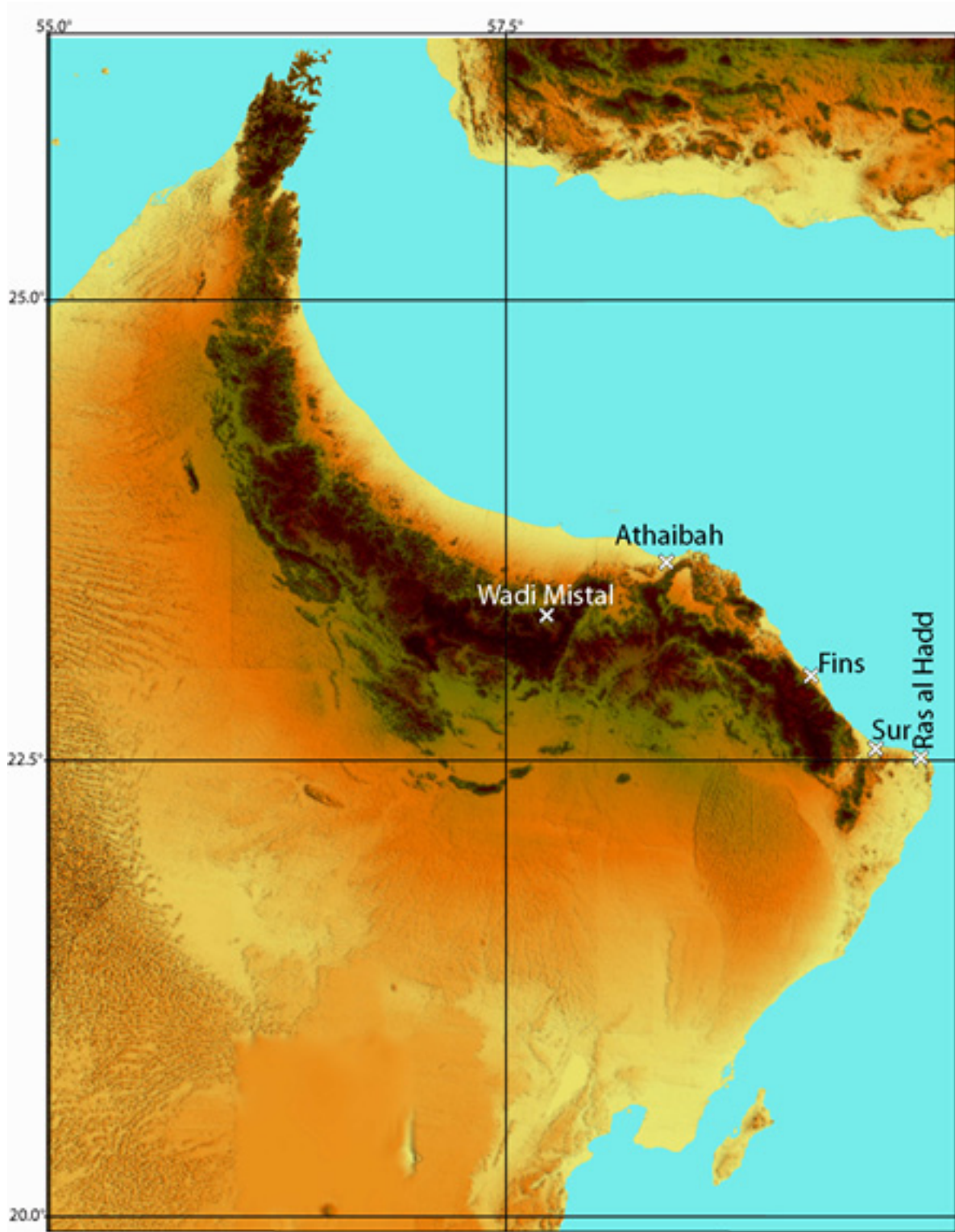


Figure 1: Digital elevation model of northern Oman and adjoining countries. The map is based on SRTM data ([http://dds.cr.usgs.gov/srtm/version2\\_1/SRTM3/Africa/](http://dds.cr.usgs.gov/srtm/version2_1/SRTM3/Africa/)) and GTOPO 30 data (<http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html>). The locations of the key-areas discussed in the text are labeled.

## 1.2 The global importance of the coastal zone

Knowledge of coastal changes and natural sedimentary processes is essential as there is a close link between the environment and the sustainable development of the society through (forced) adaptation. This link is evident since the beginning of human state formation and the establishment of state-level societies some 7000 years ago (Day et al. 2007, Kennet & Kennet 2006). Environmental changes are associated with global climate changes, which affect e.g. desertification, groundwater recharge, coastal evolution, flash-flood frequency, marine productivity, etc. and may also lead to geo-hazards of various kinds. These issues are discussed globally (McLachlan & Brown 2006) and are of major importance for the Sultanate of Oman as the natural conditions as well as the expected demographical and economical development will notably affect the Sultanate's coastal zone.

Coastal dynamics and the associated coastal changes act on different time scales and are a consequence of endogenic as well as exogenic controls (Long 2001, 2003). Endogenic forces such as isostatic crustal movements affect larger regions and operate over time spans in the order of kilo-years (Clark 2007), whereas neotectonic movements may affect smaller regions and act as short-term changes. The major exogenic force is the eustatic level of

the sea, which is linked to climatic changes (Pirazzoli et al. 1989, Zachos et al. 2001, Miller et al. 2005). All these processes may interfere with each other and in consequence lead to a shoreline either characterized as transgressive or regressive. The controlling factors of coastal evolution and coastal dynamics will modify in the future as a consequence of global climate change (Crowley 2000, IPCC 2007). "The projected changes in climate will have both beneficial and adverse effects at the regional level, for example on water resources, agriculture, and human health." (INQUA 2009).

One important factor to consider is possible changes of sea-level (Cazenave & Nerem 2004, Lambeck 1990), which worldwide is seen as a major threat facing societies living in coastal areas (Miller & Douglas 2004, Tolba & Saab 2008). Although the rate of future sea-level rise and its implications for coastal zones are still controversial (Nicholls & Cazenave 2010, Rahmstorf 2007) it is a major task to quantify the local factors controlling coastal evolution for a given location. These data form the basis for scientifically based scenarios of future developments, which are fundamental requirements to formulate adaptation strategies.

## 2 The coastal zone of the Sultanate of Oman

The coast of Oman stretches around 1700 km along the Oman Sea and the Arabian Sea and encompasses hard rock as well as soft rock sections. Along this coastline different climatic as well as tectonic settings are encountered, which result in different land use and associated population density as well as in different risk of vulnerability to natural hazards.

More than half of the population of the Sultanate (2.3 million) is concentrated along the coast in the Muscat Governorate (27 %) and the Al Batinah Region (28 %), respectively (Ministry of National Economy, 2004). As the largest cities of the Sultanate are located here the population density is highest (e.g. Muscat Governorate 162.1 person/km<sup>2</sup>). Furthermore the coastal plains of the Al Batinah Region are intensively used for agricultural purposes – due to the existence of a shallow aquifer (see Kacimov et al. 2009) - and are of major importance for the country's food produc-

tion as well as for industry and settlement. During the last decades a remarkable economic growth in combination with a positive demographic trend resulted in rapidly expanding urban areas and increased land utilization within the northeastern part of the Sultanate. This area will be of significant value for the future development of the country as well, eventually resulting in conflicting land use demands and a development potential, which is restricted by (unknown) natural limitations.

The varying climatic conditions, tectonic settings and associated natural hazards call for a holistic scientific research approach to quantify these forcing factors of coastal evolution in the geological past in order to formulate future scenarios under changing boundary conditions towards enabling a sustainable future development.

## 3 Reconnaissance surveys along Oman's coastline

### 3.1 Wadi Mistal: sedimentary evidence for landslide damming and past precipitation events

Wadi Mistal cuts through Early Cretaceous to Permian northerly dipping strata before the wadi opens to the Gubhra Bowl with outcropping Late Proterozoic units that form a geological window. At the entrance of the wadi a huge landslide (9\*10<sup>6</sup>m<sup>3</sup>) is observable

on the eastern side of the valley. Wadi Mistal is the only outlet of the Gubhra Bowl with a catchment area of 210 km<sup>2</sup>. Within the wadi we found sedimentary evidence for landslide damming (Rahn 2011).





Along the wadi sides the Mesozoic formations (mainly thick-bedded limestones) are visible. Normal faults are observable, showing offsets in the range of meters. These are especially obvious on the western side of the wadi. The eastern side of the wadi is characterised by clastic deposits. The outcrop shows two distinct units. The lower 2-3 m are made up of (semi-) rounded blocks that are floating in a silty matrix. This unit is horizontally layered. Imbrication structures within this deposit indicate fluvial transport from south to north. This sequence is overlain by an even coarser deposit. The largest grain sizes observed measure 8m in diameter. The blocks within this unit are angular, the sorting is poor and the deposit shows no sedimentary structures. The upper unit can be traced for 1km on the eastern side of the bank. Huge boulders are observable in the wadi bed and occasionally unsorted clastic deposits can be observed on the western side of the wadi as well. These deposits are interpreted as representing a rockfall and/or landslide deposit. The huge blocks in the current channel are lag-deposits. At the south-

ern end of the outcrop a pocket of pure clay deposits is observable. This clay shows ripple marks at the surface of some layers. Upstream from the landslide several outcrops were identified which reveal an up to 22m thick unit of horizontally layered fine-grained deposits. The outcrops represent erosional remnants of a more widespread deposit which probably covered the entire wadi. The location of the outcrop is in every case behind a bend in the wadi's course and is therefore protected from erosion.

The upper part of the outcrops is characterised by gravel deposits representing a fluvial facies. In total 130 fining-upward sequences were logged. Each sequence (average thickness 20cm) shows a clear transition from silt at the base to clay at the top. Some sequences show cross bedding structures. Grain-size increases upstream. Within the profiles, distinct layers characterised by desiccation cracks are observable. Furthermore in-situ plant remains are identifiable.

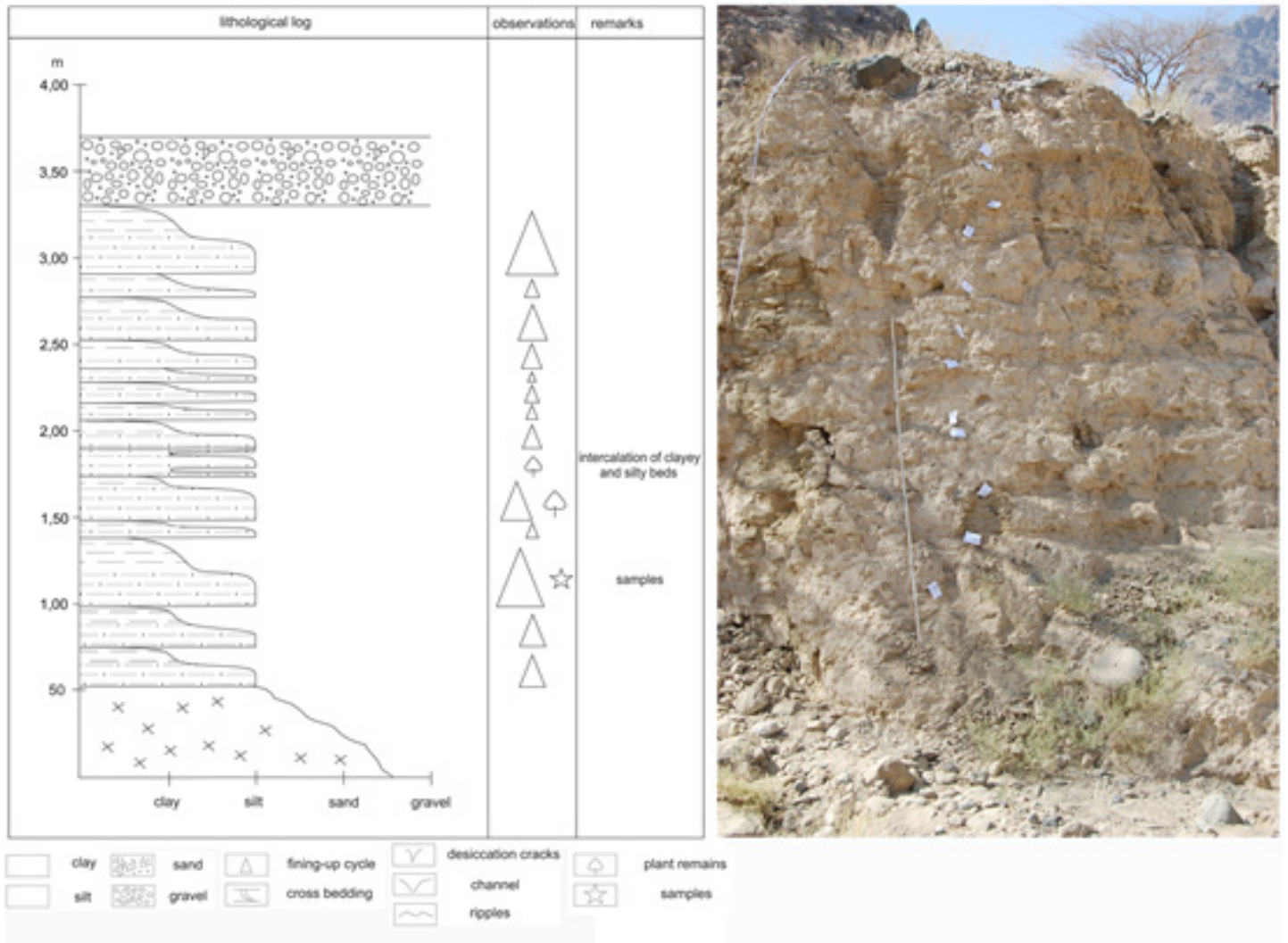


Figure 2: Lithological log and photo of the landslide-related deposits in Wadi Mistal. Note the fining upward-sequences.



Figure 3: Outcrop in Wadi Mistal: A 22m profile of fine-grained deposits with a total of 130 fining-upward sequences. Arrows indicate persons as scale.

### 3.1.1 Interpretation

The deposits are interpreted as representing (ephemeral?) limnic and fluvial deposits, which at the time of deposition covered the entire wadi. A facies shift to more fluvial conditions is encountered upstream, indicated by sedimentary structures such as cross bedding and an increase in grain-size. Desiccation cracks and plant remains indicate temporary dry conditions. The formation of the perennial lake within the wadi is seen as a direct result of the landslide at the wadi entrance which led to damming. Each individual fining-upward sequence within the profile is

interpreted as representing a precipitation event. The thickness of the sequences reflects the intensity of the event and the total number will reveal the frequency once the time-interval of deposition is known. The age of the deposits is not known at the moment. Optical stimulated luminescence data (OSL) are expected for 2011. However, remnants of a stone tower (or tomb) are visible on top of the limnic deposits. The construction resembles Bronze-age structures so that a minimum age for the landslide of 3000-5000 years is expected.

### 3.2 Beach at Al Hayl and Athaibah: coastal sediments as archives of Holocene coastal dynamics

The beach in Al Hayl and Athaibah is dominated by sands. At wadi outlets gravel is encountered which forms small delta-structures on the coast which in general is straight. Beach-rock is commonly observed along the coast in the intertidal zone. The tidal amplitude is around 2 m. The beach in Athaibah is bordered landward by a 2.0-3.0 m high cliff made up of fine to medium sand. Within the cliff profile in Athaibah a distinct shell layer is observable at an elevation of 1.5-2.0 m (Taissa 2010). This layer can be traced for several hundred meters along the coast. The most common species found in the layer are *Pinctada radiata* (pearl oyster). Besides these, corals with in-situ piddock-shells and rocks covered with marine

species are common. The rocks and coral blocks are up to 15 cm in diameter. This shell layer can be traced some decameters landward. Partly, on top of the shell accumulation a finer-grained bed of broken shells, barnacles and a variety of gastropods is found. Shells and barnacles still have mother of pearl and colors preserved.

The beach profile in Al Hayl is somewhat smoother. No cliff is observed there. Marine sediments are encountered up to 700 m landward from the modern shoreline. As the beach-profile rises landward the marine deposits are well above present mean high water level.



## 3.2.1 Interpretation

The depositional environment of the onshore marine deposits in the locations Al Hayl and Athaibah are rather speculative for the moment being. The most common species observed in the layer in Athaibah is *Pinctada radiata* (pearl oyster). Their habitat is littoral to subtidal (0-150 m) on hard substratum. The onshore marine deposits may either rep-

resent a mid-Holocene sea-level highstand, may be storm deposits or tsunami-related. A better understanding will be revealed once the sediments have been dated and a proper age-control is established. Sedimentological, micro- and macrofossil analyses are undertaken at the moment.

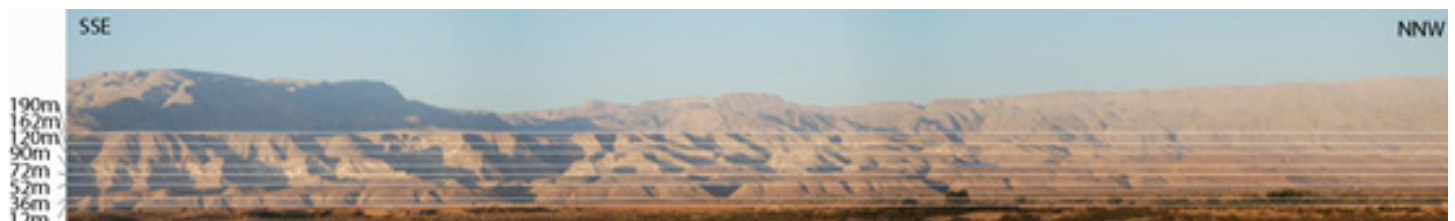


Figure 4: Panorama of the different terrace levels in Fins

## 3.3 Coastline near Fins: marine terraces as indication for Quaternary land uplift

The small village of Fins is located halfway between Quriat and Sur on the east coast of Oman. The coastline shows geomorphologic evidence of comparatively strong uplift. Stair-cased coastal terraces parallel to the coastline are encountered in elevations up to 200m. The upper most terraces are erosional, whereas the lower ones are depositional in style. In order to decipher and to quantify the uplift history we plan to use terrestrial LIDAR scanning, which allows construction of a high-resolution 3-dimensional digital elevation model. Critical for the quantitative approach is the dating of the different terraces. We expect to find molluscan and coral remains on the terrace surfaces. Kellerhals (1998) attempted to date the terraces but the results are not conclusive.

The erosional terraces are cut into Paleocene

to Early Eocene limestone formations. The limestone is karstified; sinkholes and caves are common features. The formations are dissected by NW-SE trending faults. The terrace levels below 50 m are Quaternary in age and faults are not obvious. The lowermost terrace in the intertidal zone is made up of beach-rock and raised coral reef. These rocks are fractured (Rausch 2010). No offsets were observed and no direct correlation with the faults in the older rocks seems possible. However, neotectonic activity is recorded in the area as reported by Roger et al. (1991). Furthermore, historical data point to earthquake destruction of the ancient city of Qalhat in the 15th century AD, testifying to active tectonics (Musson, 2009).



## 3.4 Sur and Ras al Hadd lagoon: sediments as archives for Holocene tsunami events

Several intertidal lagoons exist in the vicinity of Sur and Ras al Hadd. These lagoons serve as geological archives with a preservation potential for palaeo-tsunamis (see Donato et al. 2008, 2009, Panitz 2010, Wagner 2011). A devastating tsunami hit the coastline of Pakistan on 28.11.1945 following an 8.1 Mw earthquake on the Makran subduction zone. There are indications that the tsunami had an impact on Oman's coastline as well. However, there is no historical evidence. This can partly be explained by the isolation of the country during this time.

Sur-lagoon is a 12 km<sup>2</sup> large, shallow microtidal lagoon. Most of the lagoon is intertidal and access is easy during low tide. We collected seven sediment cores at various locations within the lagoon. The deepest core reaches 10m below the present surface. The sequence is characterized by silty fine sand in the lower part (10-6m) and fine sand in the upper part (6 – 0 m). Within the uppermost meter a distinct shell bed was identified. This clearly indicates an event-layer which can be either storm- or tsunami-generated. We expect to find evi-

dence for the depositional character of the layer by identifying species and state of preservation. We concentrate on the analyses of microfaunal associations (foraminifers) within the shell layer as well as in the surrounding strata, supported by sedimentological and microfaunal investigations.

The shell assemblage contains allochthonous subtidal species suggesting a tsunamigenic deposit of these layers. At a depth of 80 cm another shell deposit is located. The typical foraminiferal association of the lagoon is *Ammonia*, *Elphidium* and *Quinqueloculina*. Allochthonous species (e.g. *Oridorsalis umbonatus*, *Bolivina striatula*) are subsidiary indicating a significant distribution.

Additionally, we collected 4 sediment cores in the lagoon of Ras al Hadd (Khawr al Hajar). The samples are currently being analysed. Preliminary results indicate that a layer at 80 cm below the bottom of the lagoon could be tsunami-related.

### 3.4.1 Interpretation

An event-layer is observed both in Sur-lagoon as well as in Ras al Hadd. As it is difficult to differentiate between storm and tsunami-generated deposits further investigations along the coastline need to be conducted. Dating evidence is required to constrain the ages of the event layers. Further earthquakes which have occurred along the Makran subduction

zone are documented in 326 BC, 1008 AD, 1524 AD, 1819 AD, 1845 AD and 1897 AD (Heidarzadeh et al. 2008) These earthquakes might have also produced tsunami that affected the Omani coast. We are seeking sedimentary record of these events, in order to improve a risk assessment of tsunamigenic hazards along the coastline.



## 4. Outlook

The reconnaissance surveys conducted so far are very promising. It can be proven that both archives for the long-term as well as short-term coastal evolution exist. Additional archives need to be found in order to develop a better spatial and temporal resolution of the changes

and driving forces. Immediate tasks will be to date the different sediments, to conduct sedimentological and palaeontological analyses of the sediments collected and, finally to establish a robust timeframe for sea level changes and tectonic interaction.

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# Conference Announcement



International Conference on the Geology of the  
Arabian Plate and the Oman Mountains



## International Conference on the Geology of the Arabian Plate and the Oman Mountains (IC- GAPOM) 7- 9 January 2012

<http://www.geoman2012.com>

Please visit the conference website if you are interested in attending or submitting an abstract, or contact Dr. Iftikhar Ahmed directly at:

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The Conference will be held at the Sultan Qaboos University and both pre- and post-conference field excursions will be organized.

In a number of keynote addresses international experts will summarize recent developments in the geological understanding of the Arabian Peninsula and the Oman Mountains.

Oral and Poster presenters will share their research results in a diverse range of thematic sessions.



## A glimpse of the Cretaceous stratigraphy and hydrocarbon potential of the Jeza-Qamar Basin, a frontier basin straddling the Oman-Yemen border

By Osman Salad Hersi,

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### INTRODUCTION

The Jeza-Qamar Basin lies across the Oman-Yemen border (Fig. 1) and its Mesozoic sedimentary fill is represented by strata of Jurassic to Cretaceous age. The sedimentary fill onlaps uplifted flanks of the basin, namely the Fartaq High (FH in Fig. 1) to the west and the Marbat High (MH, Fig. 1) to the east. In the Omani portion of the basin, no Jurassic strata are known to occur, and the exposed Mesozoic section includes strata that span from Early Cretaceous (Barremian) to Late Cretaceous (Maastrichtian). The sedimentary succession is well exposed along the sea-facing cliffs of Dhofar Mountains of Jabal Samhan (north of Marbat), Jabal Qara (north of Salalah) and Jabal Qamar (north of Rakhyout and westward into the Yemeni border) (Fig. 2). The Cretaceous sequence is punctuated by regional unconformities and consists of six formations that are, in an ascending order, Qishn, Kharfot, Dhalqut, Qitqawt, Samhan & Sharwayn

formations. The Mesozoic sedimentary fill of the basin correlates well with hydrocarbon-producing units in the region (Fig. 3). However, despite its regional location and similarity of its sedimentary fill, in many aspects, with the adjacent prolific basins, the Jeza-Qamar Basin has been overlooked by exploration companies partly due to unfavorable exploration results in mid 20th century and partly due to poor knowledge of its geologic evolution and hydrocarbon potential. Researchers from the Department of Earth Sciences (SQU) have recently launched a research project (SR/SCI/ETHS/07/01) on the Cretaceous sequence of the basin, deciphering its stratigraphic, sedimentologic and diagenetic evolution, as well as its hydrocarbon potential. The main target of the project is the lower three formations of the succession, namely, Qishn, Kharfot and Dhalqut formations.

### LITHOSTRATIGRAPHY: QISH, KHARFOT & DHALQUT FORMATIONS

The oldest Mesozoic strata in the southern Dhofar are represented by the Qishn Formation. Older Jurassic rocks are reported to occur in the Yemeni side of the subsurface Jiza-Qamar basin but no outcrops are so far recognized in both Oman and Yemeni sides of the basin. Moreover, Triassic and Jurassic strata occur in the Socotra Island of Yemen; an island interpreted to have been attached

to southern Dhofar before the opening of the Gulf of Aden. Thus, the possibility of having pre-Cretaceous strata in the Jeza-Qamar Basin is indeed high and attractive. This is due to the fact that most source rocks in Yemen are associated with Jurassic strata that charged Cretaceous reservoirs.

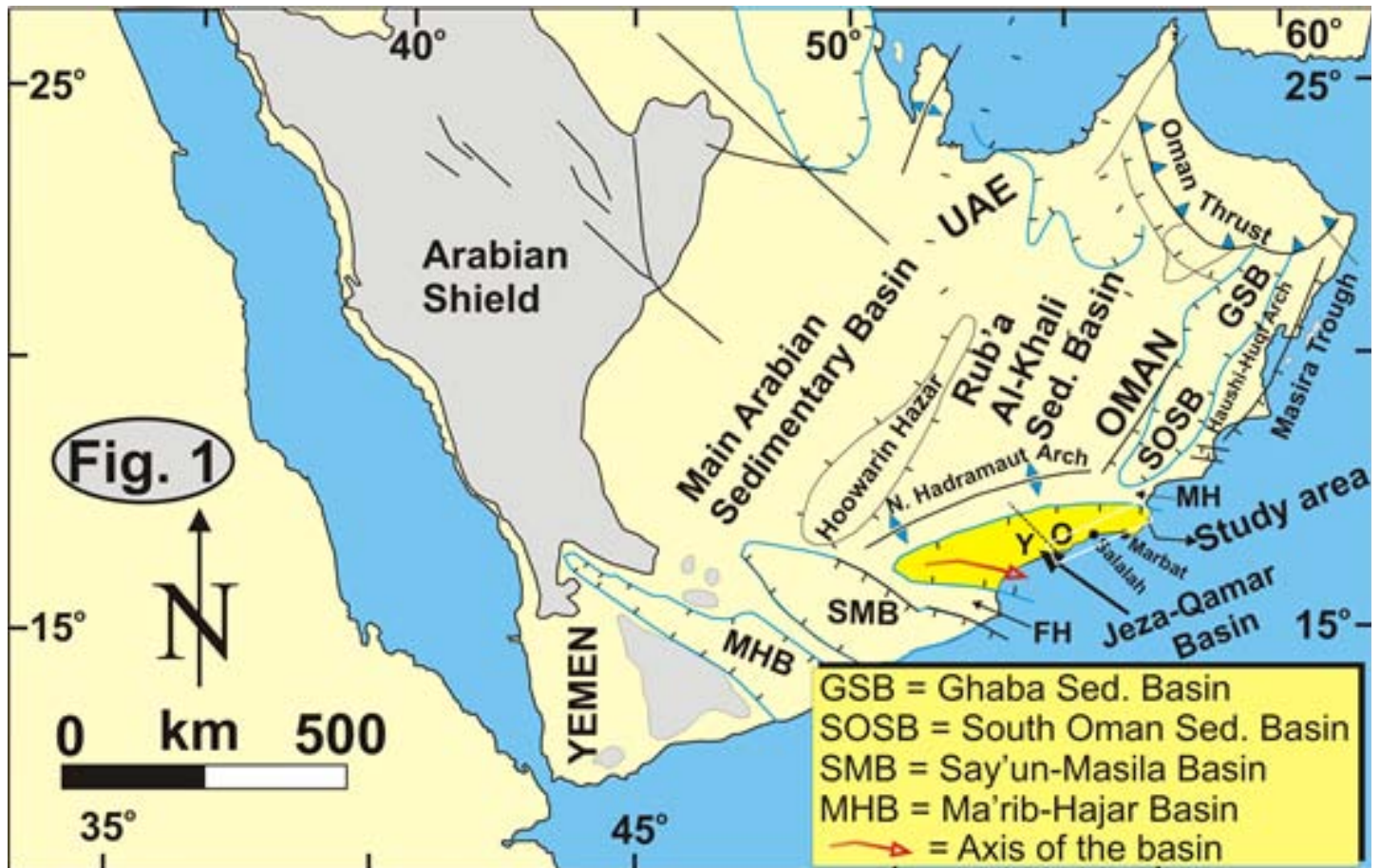


Figure 1: Regional overview of sedimentary basins.

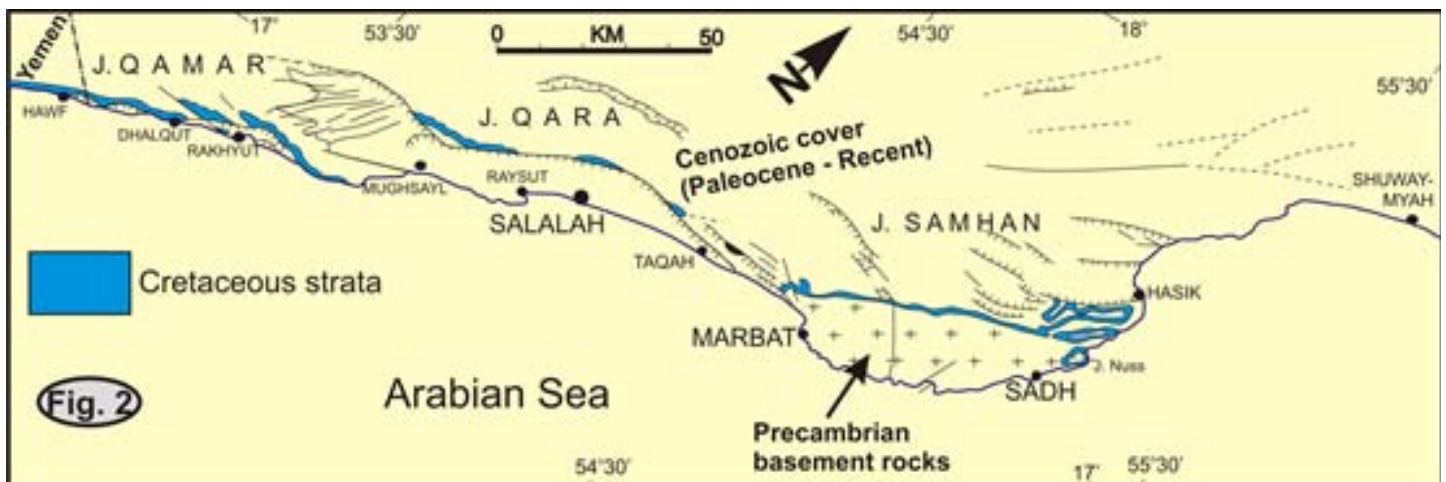


Figure 2: The Cretaceous outcrops.

The Qishn, Kharfot and Dhalqut formations are well exposed along the sea-facing cliffs of the Dhofar Mountains (Fig. 2 & Fig. 4) and brief lith-

ologic descriptions of the formations and their hydrocarbon potential are given below.

## Qishn Formation (Barremian to middle Aptian)

This formation unconformably overlies various types of rocks that include the Precambrian Marbat crystalline rocks, the glaciogenic Neoproterozoic Marbat Group or the Proterozoic Al-Hotta-Ain Sereit metasediments. The formation consists of three members: Shabon, Hinna and Hasheer (Fig. 3). The Shabon Member consists of thickly bedded, massive to cross-bedded, coarse-grained sandstone interbedded with dark gray and orange (rusty) fine-grained sandstones and mudrocks. The overlying Hinna Member is characterized by thinly- to thickly-bedded, well-cemented, bioclastic mudstones and wackestones interbedded with poorly-cemented, burrowed, nodular, bioclastic mudstones (marls). The bioclastic content increases upsection where medium to thin beds of bioclastic and (local) oolitic packstones / grainstones also occur. The Hasheer Member consists of (i) locally nodular, bioclas-

tic packstones and grainstones, (ii) thick interbeds of bioclastic grainstones to rudstones, grainstones and coarse-crystalline (sucrosic) dolostones, and (iii) thickly to medium bedded bioclastic wackestones to packstones. The Qishn Formation was deposited during a third-order sea level rise where the Shabon Member documents initial transgressive deposits (marginal marine sedimentation punctuated by intermittent exposures). The upper part of the member is characterized by *Orbitolina*-rich marls that are interpreted to represent the deepest depositional setting (maximum flooding facies). The Hinna Member represents low energy, relatively deeper lagoonal to inner shelf (lower part) to middle-shelf (upper part) setting followed by high-energy sand shoals of the Hasheer Member.

## Kharfot Formation (early to middle Albian)

The Kharfot Formation is about 100 m thick in the eastern part (Jabal Samhan area, Fig. 4) to more than 300 m in the western part of the studied area (Wadi Kharfot and Wadi Sayq area). Thickness variations are accompanied by lithologic differences between the eastern (Jabal Samhan) and western areas of exposures. In the east, the formation can be roughly divided into two units: a lower one dominated by interbeds of *Orbitolina*-rich marls and bioclastic wackestone to packstone lithofacies and an upper one of thickly bedded, cleaner limestone of bioclastic packstone capped by rudistic rudstone. Occasional rudist and oyster biostromes occur in the western part of the study

area. Throughout the study area, the top of the formation is marked by a prominent hardground surface followed by the shales of the Dhalqut Fm. The overall depositional setting of the Kharfot Fm. is envisaged as a west-facing, gently-sloping ramp that documents a rising sea level represented by the inner to middle platform succession represented by the *Orbitolina*-rich lower unit followed by a relative drop in the later stages of the formation as represented by the shoaling-upward succession represented by the rudistic rudstones that cap the formation.



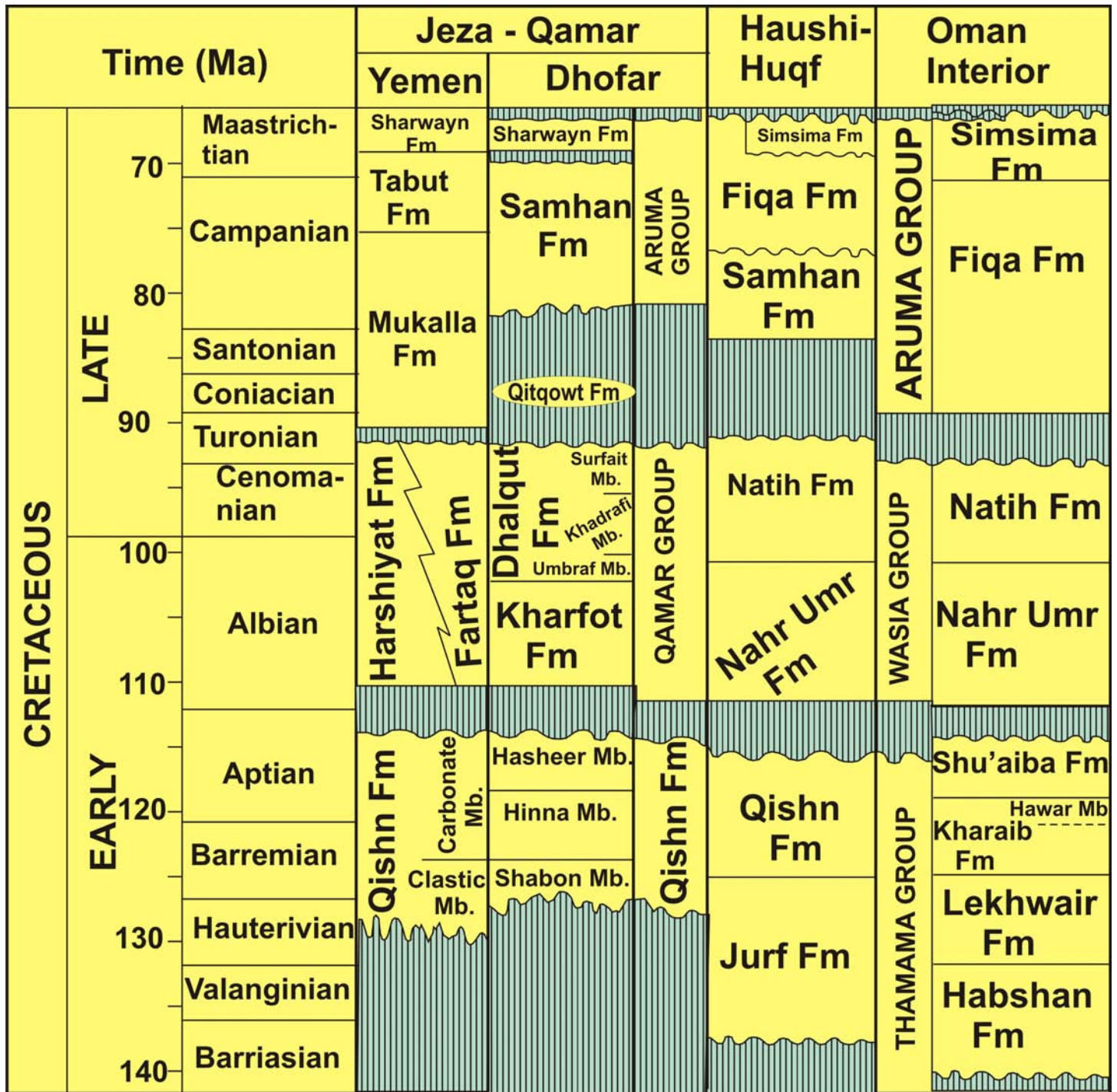


Figure 3: Stratigraphic overview and correlation with central and northern Oman.

## Dhalqut Formation (late Albian - early Turonian)

This formation conformably overlies the Kharfot Formation and consists of three members: Umbaraaf, Khadrafi and Surfait, in ascending order (Fig.3). The Umabraf Mb. is dominated by orbitolina-rich shales and marls with occasional oyster- and rudist-rich biostromes and storm-deposited bioclastic and/or oolitic grainstones. The Khadrafi Mb. consists of alternating thick beds of bioclastic wackestone to packstone (locally rudist biostromes) and Orbitolina-rich marls. The Sarfait Mb. is characterized by thickly to massively bedded, clean bioclastic mudstone / wackestone to rudstone lithofacies. Minor medium crystalline dolomite horizons are present in the member. The over-

all depositional setting of the formation is a cleaning-upward shallow marine carbonate platform. High fine siliciclastic influx in a relatively deep-shelf environment represented by the shales and Orbitolina-rich marls of the Umbaraaf Member was the depositional norm of the basin during late Albian time. This was followed by reduction of the siliciclastic influx and increase of the carbonate facies giving way to the interbedded lithologies of the Khadrafi Mb. Almost total cessation of the clastic input and establishment of high energy, rudist-rich carbonate shoals took over the depositional site during the Cenomanian and early Turonian stages.

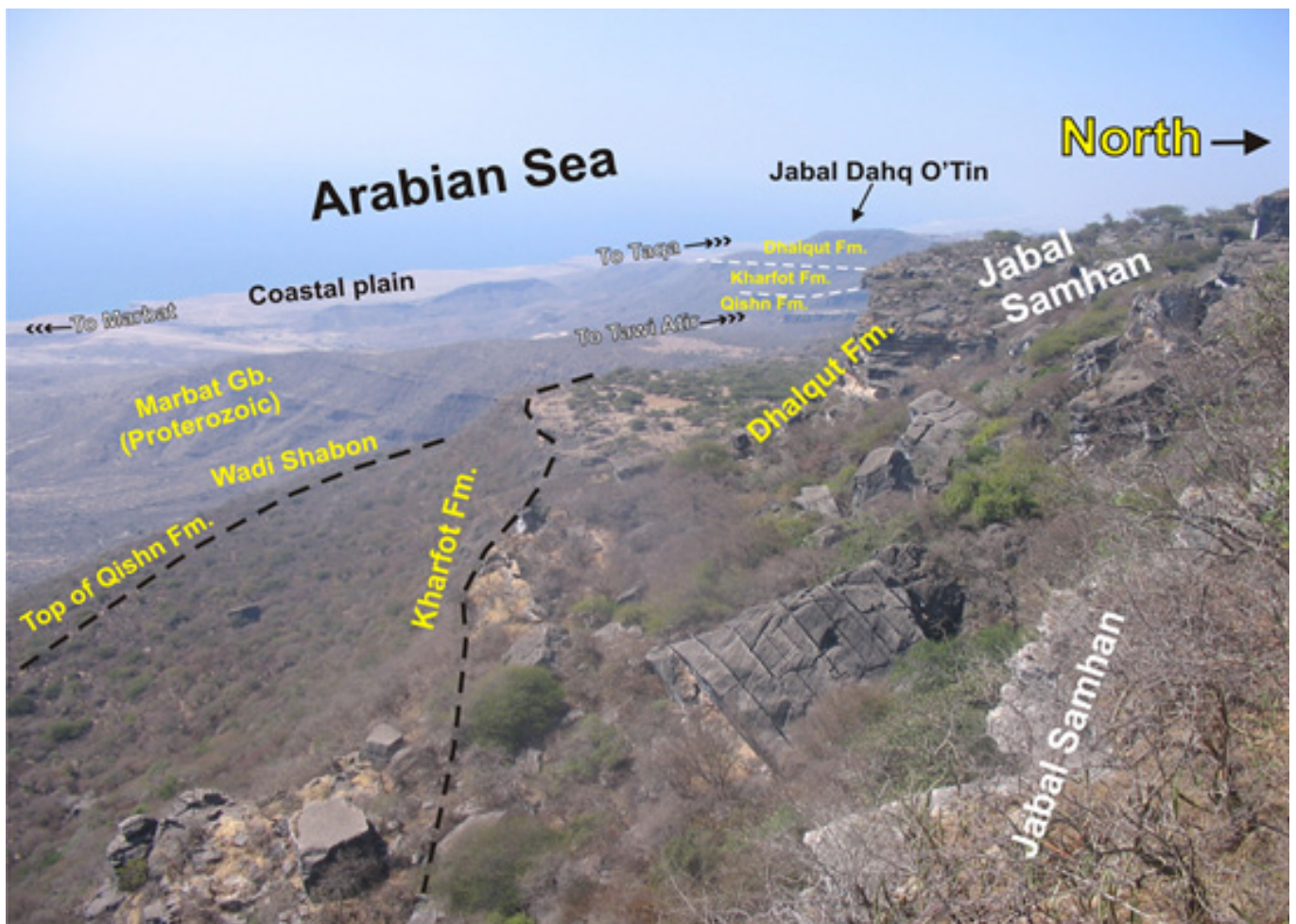


Figure 4: Jabal Samhan view.



## THE HYDROCARBON QUESTION

The most attractive reservoirs in this stratigraphic succession are the Shabon sandstones (Por. up to 25%), Hasheer dolomites (Por. up to 15%), the bioclastic / oolitic grainstone lithofacies of the Umbaraaf Mb (Por. up to 15%) and the thick Sarfait Member (Por. = 5% to 15%, particularly where dolomitized). The late Jurassic Madbi shales and Naifa carbonates, rock units that sourced the oil in the adjacent Say'un-Al-Masila Basin (Yemeni side of the basin). Furthermore, organic-containing intervals also occur in the Hinna Mb, Kharfot Fm and Khadrafi Mb and the lower part of Sarfait Mb. Structural elements associated with intermittent late Cretaceous to Cenozoic tectonic activities

and lateral facies changes define significant structural and stratigraphic traps. Existence of tight mudstone and wackestones (e.g., the Hinna Mb and the Kharfot and Dhalqut formations) are considered to be potential cap rocks that could seal potential hydrocarbons in the Cretaceous reservoir horizons. Occurrence of pyrobitumen in the certain horizons of the Dhalqut Formation and recent gas discovery in the Yemeni side of the basin further underscore a mature hydrocarbon system in the basin. In conclusion, the Jeza-Qamar basin contains a promising petroleum system and awaits a daring exploration move from the industry.

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## Regional Exploration News

### INDIA

ONGC has notified the Directorate General of Hydrocarbons of three further discoveries, one each in the Cambay Basin and Krishna Godavari onshore basin and one new discovery in the KG shallow offshore basin. Aliabet 2 in NELP block CB-OSN-2003/1 in the Cambay Basin was drilled to a depth of 2,107m. A drillstem test in the interval 1,890-1,896m flowed 450 Mcfg/d and 38 bc/d from the Eocene Hazad Member of Anklesvar Formation, opening up a new play in the area. On further testing after notification to the DGH, the well flowed 2.72 MMcfg/d and 69 bc/d through

6mm choke; the earlier lower production is attributed to the lower levels of draw-down. Well Malleswaram 1 in PEL block 1A in Krishna Godavari onshore basin reached a total depth of 4,105m and drillstem tests at 3,518-3,509.5m and 3,508.5-3,503m flowed 300 bo/d and 400 Mcfg/d. The new pool discovery is GS-29 6, drilled in 95m of water in the Krishna Godavari Basin to a total depth of 2,502m. Two sandstone intervals were tested which flowed a combined 7,470 b/d of 38o API oil and 8.6 MMcfg/d.

### IRAN

Naji Sa'douni Managing Director of the Petroleum Engineering & Development Company (PEDEC) says the US\$ 1.5 billion Darkhovin Phase III development project to add an additional 80,000 bo/d to field output will be awarded "to a consortium consisting of some local companies and PetroVietnam within the next couple of months." During the third quarter of 2010, Dana Energy submitted a development proposal for the Darkhovin Phase III development to PEDEC. ENI had participated in earlier development phases, which brought field production capacity up to 160,000 bo/d, but it stated in an SEC Form 20-F filing on 29 April 2010 that "activities are progressing to hand over operatorship of the Darkhovin (also known as Darquain or Darkhovein) oil field to

the local partners as development activities were concluded at this field in 2009." It outlined its intention to withdraw from the project because, "It is possible that in future years, ENIs activities in Iran may be sanctioned under relevant US legislation," implying that Darkhovin Phase III development was likely to be delayed. The second development phase of Darkhovin oil field in southwest Iran is officially now onstream, with oil minister Masoud Mirkazemi attending the opening ceremony. The oil field's second phase came onstream at a cost of US\$ 1.3 billion and will increase the field's oil production capacity from 50,000 b/d to 160,000 b/d while some 280 MMcfg/d will also be produced in the field.

When the third and final phase is completed in five years time, Darkhovin's production capacity will reach 260,000 b/d. While most Western firms have exited Iran following sanctions imposed on Tehran over its controversial nuclear program, ENI has reportedly signed a US\$ 1.5

## IRAQ

Longford Energy, a junior Canadian oil and gas exploration and production company, says that DeGolyer and MacNaughton has completed an independent resource assessment of the Chia Surkh Production Sharing Contract (PSC) in the Kurdistan Region of Iraq in which it holds a 40% interest. DeGolyer has established a "best estimate" or P50 gross unrisksed contingent resources of 60.22 MMbo for the Jeribe Formation and 13.34 MMbc and 283.79 MMcfg for the Shiranish Formation. DeGolyer has also established a "best estimate" or P50 gross unrisksed prospective resources of 217.31 MMbo and 2.7 MMcfg for the block. Long-

ford completed the acquisition of 307 km of 2D seismic in late 2010. Two wells are planned for drilling in the Chia Surkh Block, with the first due to spud on the Chia Surkh field in the June 2011 with a planned total depth of 2,400m. Longford was appointed as operator of the block on 15 March 2010. Longford completed the acquisition of 302km of 2D seismic in November 2010. The company was formerly known as Longford Corporation and changed its name to Longford Energy in December 2007. It is headquartered in Calgary, Canada.

## Jordan

Karak International Oil, a subsidiary of UK-based Jordan Energy & Mining Ltd (JEML) has signed a concession agreement with the Jordanian government to exploit a portion of the country's extensive surface oil shale reserves. Under the deal, signed in Amman by Jordan's minister of energy and mineral resources Khaled Toukan, JEML would extract oil from the 22 sq km Al Lajjun block some 110 km south of Amman. The deal follows a memorandum of understanding JEML signed with the Natural Resources Authority in November 2006. According to Karak Al Lajjun shale has excellent characteristics:

- Near surface (<30m waste covering around 30m of oil shale)
- High oil content (>11%)
- Low moisture levels (2-3%)
- High level of total organic material (>20%)
- Thick seam with consistent quality (~30m)
- Low stripping ratio (1:1).

Al Lajjun will produce first oil and power in 2014 when production will average 15,000 b/d rising to 30,000 b/d in 2020 and 60,000 b/d by 2026.

## OMAN

Raoul Restucci, Managing Director of Petroleum Development Oman (PDO) and Nasser bin Khamis al Jashmi, Under-Secretary at the Ministry of Oil and Gas (MOG) as well as a member of PDO's board of directors, have reported the discovery of a large gas field at Khulud West, in addition to four new oil fields at Amal Southeast, Aqeeq, Sayyah and Al Ghubar East amounting to over 800 MMboe in place.

## PAKISTAN

Located in the northeastern part of the Tal EL (Potwar Basin) onshore concession, MOL says that its Tolanj X-1 exploration well is a gas discovery. At a depth of 4,787m within the Cretaceous Lumshiwai Formation, an openhole drillstem test carried out in the up-

Oman's oil and condensate increased by 6% in 2010 to average 864,600 bo/d while natural gas production averaged 3.22 Bcf/d, an increase of 7% over the previous year. In addition to PDO's achievements in 2010, special mention was made of CCC subsidiary CC Energy, a new operator which initiated production during the year.

per 48m of Lumshiwai Formation reportedly flowed 16.3 MMcfg/d through 32/64" choke at a wellhead flowing pressure of 2,392 psi. Drilling continues to a revised total depth to target the deeper horizons.

## SYRIA

Sufian Alaw, Syria's oil minister has hinted that awards will be announced for the four blocks – 3, 5, 7 and 12 – that received bids in the 2010 international bid round. The minister also stated that in the same timeframe, three offshore blocks will be offered in a new licensing initiative that seeks to draw international companies interested in exploration drilling in the area following the recent big Leviathan discovery. The new round for offshore exploration will mark the third attempt

by the Syrian government to revive interest in its offshore waters after two previous tenders. Analysts believe that following the potentially giant Leviathan gas find by Noble Energy and significant gas discoveries in Egypt and the Gaza Strip in recent years; the industry appetite for Syria may have changed. Syria aims to boost its crude oil production, which has declined from 590,000 b/d in 2006 to around 380,000 b/d.



## UNITED ARAB EMIRATES

In a move that IHS World Markets Energy believes underlines the determination of Abu Dhabi National Oil Co. (ADNOC) to break up, or diversify, the number of players in the two mega-concessions dominated by supermajors, Korean National Oil Company (KNOC) has signed a preliminary agreement with ADNOC covering a number of issues. Hailed as the largest-ever oil development project won by South Korea, KNOC is to delineate and develop three as yet unnamed oil discoveries with total reserves of 570 MMbo. Full awards are to be signed by 2012, with production scheduled to begin as

early as 2013. In addition, the statement indicates that KNOC will also be allowed to take part in the exploration & development of other major oil fields with more than 1 billion barrels in reserve once current production contracts with other nations expire starting from 2014. South Korea and Abu Dhabi signed an additional MOU agreeing to store 6 MMb of Abu Dhabi crude oil in South Korea's storage facilities for free, to enable strategic co-stockpiling and be allowed to use the stored crude in an emergency.

## YEMEN

Midas is seeking to farm down a significant proportion of its 93% holding in the 679 sq km Ghayl Bin Yumain Block 68 concession prior to drilling the Al Hadi 1 prospect during the second half of 2011. Block 68 was created from the acreage that was released when DNO Yemen made a 25% partial relinquishment of its 2,717 sq km South Howarime Block 43 concession, prior to entering a second exploration phase in November 2002. With a planned total depth of 2,600m, Al Hadi 1 is intended to target a fractured Basement play, with secondary Qishn and Kohlan formation objectives.

DNO is preparing to suspend the Gabdain 1 fractured Basement wildcat in the northern sector of Block 72 (Ain) after testing up to 180 b/d of 39° API oil during a five-day test of the Kohlan clastic section. Drilled to a total depth of 3,485m, an openhole test of the top Basement section from which oil samples were collected failed to flow, following which testing of the overlying Kohlan gravel wash commenced using a small electric submersible pump. The company is preparing to undertake an early appraisal well.

With thanks to **IHS Energy**

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